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PLANT PROTECTION OVERSEAS REVIEW

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PLANT PROTECTION LTD

PLANT PROTECTION OVERSEAS REVIEW

A PERIODICAL SURVEY OF NEW DEVELOPMENTS IN THE CONTROL OF PESTS, DISEASES AND WEEDS

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ILLUSTRATIONS

Fig. 1.—The use of 'Agroxone' on Rice in Italy. } *Inset*
Fig. 2.—Campaign Against the Moroccan Locust in Northern Iraq. }

EDITORIAL

THE greater part of this number is devoted to weed control problems. Articles on this subject have been selected with the object of showing how different countries are attacking the problem. We hope in future numbers to print further articles illustrating up-to-date weedkilling methods and contributions from our overseas readers on this subject for publication in the *Overseas Review* will be most welcome.

We are very anxious that this *Review* should be regarded as a suitable medium for the expression of views on all matters relating to the protection of crops. Circulation of this *Review* is world-wide and increasing with every issue. The Editor will be glad to consider publishing articles not only on Weed Control but on insecticides, fungicides and their practical application in the field.

"Agricultural Machinery Journal"

The Circulation Manager of the above journal will be pleased to forward a complimentary copy to all readers of *Plant Protection Overseas Review* who care to write to him at 1, Dorset Buildings, Salisbury Square, Fleet Street, London, E.C.4.

I—GREAT BRITAIN

"UP-TO-DATE WEEDKILLERS"

(*Paper read to the Farmers' Club, January* 3, 1949)

By Dr. E. HOLMES

(*Reproduced by kind permission of the Farmers' Club from their Journal Part* 1, 1949).

SO much has been said and written about weedkillers in recent years that I am a little fearful of addressing so distinguished a gathering on the subject. I shall perhaps be on firmer ground in dealing mainly with the newer so-called hormone weedkillers, since I have been privileged to take some small part in their research and practical development. However, we must have the whole subject in proper perspective.

There are many definitions of weeds, but that I normally use on these occasions is one of the simplest—*a plant growing in the wrong place*. This, of course, covers the fact that the grasses, which constitute the main agricultural crop in this country, become weeds when growing either in the garden path or among arable crops. It also covers the poppy, which is fine in a flower garden but a great nuisance in cereals. Such considerations lead to a separation of weeds into two classes, general weeds, such as the mixtures that grow on farm roads and stack yards, and specific weeds which grow and compete with agricultural crops.

Similarly, we must divide chemical weedkillers into corresponding classes—those which are toxic to all forms of vegetation, and the more selective ones which will kill one or more species in the presence of others, without damaging the latter.

GENERAL WEEDKILLERS

The general weedkillers cover rather a wide range of chemical types, the most popular being those based on sodium arsenite, coal tar emulsions and sodium or other chlorates. None of these is entirely satisfactory. The arsenicals are obviously poisonous ; coal tar emulsions are caustic and not particularly efficient ; whilst the chlorates are very

efficient but, under some conditions at least, involve fire hazards. Products which have been used for the same purpose but are not so well known are the thiocyanates and the sulphamates, the latter having been suggested in the U.S. in the last decade.

It may be noted that to give a really good kill of all forms of plant life in this country, *i.e.*, weeds which may be growing on roads and paths, sodium arsenite and sodium chlorate need to be used at the rate of about 1 to 2 cwt. per acre, especially if a residual effect is desired over a substantial period.

At this point I would interpolate a small, significant story, which happens to be true. Some years ago I had several terrific arguments with my company's senior sales manager regarding the rate of application we recommended on our containers for weedkillers such as sodium arsenite and sodium chlorate. He said they were perfectly adequate, I said they needed to be doubled. We finally resolved the difference when I explained that on my garden paths I used ½ lb. of sodium chlorate in a 2-gallon can of water and applied this evenly to every 10 square yards. At that point my colleague jumped in and said—"Yes, *evenly*, but have you ever watched the average amateur apply weedkiller? He normally applies a lot where he can see weeds and the merest sprinkle where there are none. In other words, he applies the effective dosage at the point where it will do most good." Well, my colleague knew the psychology of his customers best, but I still maintain that my own method is superior if, as I do, you require your paths free of weeds from, say, Easter one year through to the end of the following year.

SELECTIVE WEEDKILLERS

The prime interest of a predominantly agricultural gathering is, of course, in selective weedkillers which, at an economic cost, will kill out deleterious weeds without appreciable harm to crop plants. Quite early in the present century it was noted that if corn crops were dusted with the fertilizers kainit or calcium cyanamide, or if they were sprayed with comparatively dilute solutions of copper sulphate, then many of the broad-leaved weeds were killed without any very serious effects on the cereals. In 1911 it was discovered in France that dilute solutions of sulphuric acid would similarly kill out broad-leaved weeds such as the charlocks without appreciable damage to the crop. In the 'thirties and again in France, it was discovered that the chemical dinitro-ortho-cresol (D.N.C.) was equally effective against a rather wide range of weeds and again did comparatively little crop damage.

More recently a number of derivatives of D.N.C., the sodium and ammonium salts,and a number of compounds such as dinitro-secondary-butylphenol have emerged as very effective weedkillers in a number of directions. It is a pity that they are nearly all poisonous and dermatitic.

Some of these chemicals are thought to act because of morphological differences between weeds and crop plants. For example, sulphuric acid sprays are retained on the broad and sometimes hairy leaves of a number of predominant weeds and kill them by a direct corrosive action. On the other hand, the droplets of this same spray run down the vertical smooth surfaces of the cereal crop without doing any more than superficial damage to the unimportant outer leaves.

PLANT GROWTH REGULATORS

I come now to the discovery of what I regard as the scientifically most interesting and most important development of the so-called hormone weedkillers. Most important because although present "hormone" weedkillers do not fill all our requirements, they have established a completely new principle which already has wide practical applications and will have wider.

The more correct term for plant hormone is plant growth regulator. In order to give you the logical background to this development, and if you will forgive a simple lesson in botany, I would like to go back to an original observation made by Darwin in 1880. He noticed that when an oat coleoptile—that is, the first shoot emerging from a germinating oat seed—is grown in the dark and then exposed to light from one side, it promptly bends towards that light. Further, he noticed that if the tip of the coleoptile is removed, then no curvature takes place on exposure to light.

In the next 50 years a number of similar observations were made by various research workers. If incisions are made across the lateral veins of the tip of an oat coleoptile no effect is produced on its sensitivity to light. Next it was noticed that whilst a decapitated coleoptile is insensitive, this sensitivity can be restored by replacing the tip on top of a small piece of agar in contact with the rest of the coleoptile. Insertion of a small mica plate in an incision on the shaded side of the coleoptile prevents response, whilst insertion in the lighted side has no effect on the normal bending. At a later stage it was found that replacement of a coleoptile tip to one side of the rest of the coleoptile—that is, over only one of the two lateral veins—causes bending away from that side, even in the absence of light. Still later again, it was found that pieces of agar which have been in contact with coleoptile tips for some time will also bring about these bending effects in the absence of light.

Now this series of apparently trivial observations by botanists, working in the dimmest of red light in the laboratory, may seem a little futile to a farming audience. But it did lead to the important deduction that something produced in the growing tip of the plant must be responsible for the rate of growth of the cells in that plant. The bending of the coleoptile was brought about by the fact that

this growth substance in the tip, under certain conditions, only affected the cells on one side of the coleoptile. As these grew faster than those on the other side, obviously the coleoptile had to bend.

Isolation of Plant Growth Regulators

In the years around 1930 the organic chemist became intensely interested in this field and by 1933 research workers had isolated and determined the composition of two plant growth regulators which they called auxin-a and auxin-b. In the following year they isolated a third auxin which they termed hetero-auxin and this time they were able to identify it with the organic chemical, beta-indolyl acetic acid, which is fairly readily synthesised in the laboratory.

It should be mentioned that these isolations were not made by extracting millions of oat coleoptiles, but from human urine which had been observed to produce the same bending effects. The compounds have, however, since been isolated from plants, but so far the first two I mentioned have defied synthesis in the laboratory.

My colleague, Dr. Templeman, who has worked on this subject for many years now at Jealott's Hill, always illustrates the extreme activity of these substances by quoting the fact that 1 mg. (about 1/30,000 of an ounce) of auxin-a is sufficient to produce a curvature of 10 degrees in 50 million oat coleoptiles !

It has frequently been suggested that some of the virtues of farm yard manure as compared with chemical fertilizers is due to its content of these growth-regulating substances, but this has never been established by proper experimental work.

Plant growth regulators have found practical application in a number of ways—for example, in promoting the more rapid rooting of cuttings ; for the prevention of pre-harvest drop in fruits such as apples and pears ; for the parthenocarpic production of fruit (that is, causing fructification without fertilisation) ; in the prevention of sprouting of potatoes and so on. It is possible that further outlets may be found in the retardation of bud development of fruit in the spring, thus avoiding frost damage, and the increase of speed of union of grafts with scions.

DISCOVERY OF " HORMONE " WEEDKILLERS

Just before the war, Dr. Templeman was carrying out a piece of work at Jealott's Hill in an endeavour to discover whether the application of these products to seeds, cuttings or plants could produce an increase in total yield in the subsequent crop. Practically all his observations in this direction were negative, but in 1940, in the course of an experiment in which he sprayed boxes of soil containing mixed seeds of oats and yellow charlock, he noticed that the synthetic chemical, alphanaphthyl acetic acid, applied at rates of the order of

10 to 25 lb. per acre, almost entirely suppressed the germination of the weeds without effect on the oats. This was followed by similar observations when mixed cultures of the same plants were sprayed. This, to the best of our knowledge, was the first observation of the selective effect of this type of chemical on different plant species.

Alpha-naphthyl acetic acid at the dosages mentioned was completely uneconomic from the farmers' point of view. In consequence, under the direction of that well-known research chemist and farmer, Dr. R. E. Slade, a very considerable programme of experimental work was arranged with another colleague, Dr. Sexton of the I.C.I. Dyestuffs Division Laboratories at Manchester. As the result of the examination of a very large number of synthetic chemicals, two particularly active ones were discovered in 1941 and 1942, namely, methyl-4, chlorophenoxyacetic acid and the corresponding 2,4,dichloro-acid. We call the sodium salt of the first of these 'Methoxone,' whilst the second has become generally known as 2,4-D. Professor Blackman for his part has named them M.C.P.A. and D.C.P.A. respectively.

It may be mentioned that rather later relevant observations were made both by research workers at Rothamsted and in America.

I am afraid I have taken up rather a long time in the historical introduction to this part of my subject, but I think you will agree it is desirable to give an appropriate background to the work and, at the same time, to give credit to the discoverers of these new products of interest in agriculture. I would stress that the new weedkillers were the outcome of what started out as purely academic research.

So far as this country is concerned, experimental work both by my colleagues in I.C.I. and by the Agricultural Research Council during 1943 and 1944 had developed to such an extent that wide-scale trials all over the country were justified in 1945.

I myself was responsible for some 111 trials, carried out in England, Wales and Scotland, which gave us a tremendous amount of useful information which has subsequently led to the widespread use of 'Methoxone' (M.C.P.A.) and 2,4-D (D.C.P.A.) on cereals and other farm crops.

Mode of Action

We know that these chemicals cause twisting and discoloration of the stems and leaves of weeds, that they cause a thickening and weakening of the stems, particularly just at ground level, and that they may cause the production of rootlets at most unusual points on the plant. Why this happens, and the exact mechanism within the plant are not known, but the ultimate result is the death of the weed, which is the important point to the agriculturist.

Time of application is not very important when dealing with such susceptible weeds as the charlocks. They may be killed any time from their initial emergence right up to the flower stage, although obviously it is best to kill them as early as practicable to avoid loss of crop due to competition of weeds for plant food, moisture and so on. Probably the best time to control the sensitive weeds is when cereals are about six inches high and the weeds big enough to make sure you can hit them.

With other weeds, timing may be extremely important. For example, with ragwort and docks the early seedling stage gives best results. On the other hand, with thistles it is best to apply " hormone " weedkillers when the weeds are at least three parts grown, *i.e.*, just before flowering.

Speed of action of these new types of weedkiller is comparatively slow, and whilst results may be seen on sensitive weeds within 12 hours in really hot, dry weather, it may be a week or even several weeks before positive results show on the more resistant weeds. Weather conditions may affect speed of results but not the ultimate result, provided rain does not occur within a few hours of the actual application. " Hormone " weedkillers are most effective on weeds that are growing vigorously.

Commercial Products

The number of commercial products available is increasing extremely rapidly, particularly in America, and this can be quite confusing to the ordinary user. It should perhaps be explained that M.C.P.A. and D.C.P.A. are normally available as the water-soluble sodium salts, or actual solutions, and these are the two which have been mainly used hitherto in this country. In the case of D.C.P.A., *i.e.*, 2,4-D, the solubility of the sodium salt is rather low so that means are sometimes sought to increase this property. The easiest way is to convert it to what we, as chemists, call an amine salt, and perhaps the most popular is the triethanolamine salt. In addition, and again in America, a great deal of experimental work and publication has taken place with the esters of 2,4-D, that is, combinations of the 2,4-D acid with various alcohols. It may therefore be of some interest to give a brief comparison of the efficiencies and other properties of these three types of " hormone " weedkiller. Broadly speaking, and there are always exceptions to any general statement, the sodium salts of M.C.P.A. and D.C.P.A. are the cheapest and safest on crop plants. On the other hand, the esters are appreciably more effective, but also appreciably more expensive and very much more damaging to crop plants. The amine salts are usually intermediate in all respects.

My own view is that the sodium salts are perfectly adequate and the safest for use on cereal crops in this country.

Why, then, you may ask, has so much work been done with the amine salts and esters? The answer to the first is simply that low-volume methods of application have come into vogue and the sodium salt of 2,4-D is insufficiently soluble to provide convenient solution concentrates. The esters, on the other hand, are not water-soluble and need to be dissolved in oil and the solutions emulsified before they can be used in an aqueous medium. On the other hand, the esters are very much more effective on difficult species such as scrub bush on paths, under power lines, and against such pernicious plants as brambles. They are also retained much better on the plant surface, and are therefore more effective under adverse weather conditions, such, for example, as where rain occurs soon after application.

Costs and Results

Commercial weedkillers based on these plant growth regulators may be applied either as dusts or sprays, but broadly speaking, dusts require to be used at about double the amount of active principle per acre to give the same biological effect as the sprays. In fact, our own experience over the last three years suggests that 1½ gallons of 'Agroxone' liquor per acre, containing 1.7 lb. of active 'Methoxone' (M.C.P.A.), is the average for all farm purposes, and does the same weedkilling job as 2½ cwt. of a 1 per cent dust containing 2.8 lb. of the same active material.

The obvious reaction of any farmer new to this type of product is to ask how much such applications cost and what are the benefits. Typical costs vary, according as the farmer applies the product himself or utilises the services of a contractor, anything from 25s. to about 55s. per acre.

Under experimental conditions we have obtained increases of crop yield as the result of such applications from nothing, in the presence of very few weeds, up to 150 per cent increase in heavy infestations, whilst all of you know of instances where weeds have been so bad that the crop has had to be ploughed in. My own estimate is that, with an average to bad infestation of weeds such that some form of weed-killing is called for, the average increase in cereal yield as a result of weedkilling is at least 20 per cent. Arising out of this I had intended giving tables showing possible benefits on various crops in different parts of the country. I found, however, that this may lead to mis-understanding since you know particular local conditions so much better than I do.

I will therefore content myself with a single example. The farmer who happens to obtain a yield of wheat, on weed infested land, equivalent to the national average over the last 10 years of 18.47 cwt., and who obtains the present price of 22s. 9d. per cwt., could expect an increased return of some 84s. from successful weed control. Best returns are obtained on land which is high yielding *except for weeds.*

There are, of course, other benefits over and above actual increase in yield. For example, as you will appreciate, a clean crop involves less handling and easier drying in the stook, whilst fewer weed seeds are left to give trouble in the follow crop. Removal of weeds often removes alternative hosts for other pests.

RESULTS ON PARTICULAR WEEDS

I would like now to give you a few comments on specific uses of these products against particular weeds. Weeds such as yellow charlock, white charlock (or runch), pennycress and so on, can very easily be killed in cereal crops with about 1 to 2 lb. of active material per acre, applied through conventional farm equipment. I must say, however, that these rates are based on the not unreasonable assumption that the average machine available on the average farm after a few years of use is not a very efficient instrument.

I will go further and say that whereas Dr. Templeman has shown that under experimental conditions he can obtain complete control of a heavy infestation of yellow charlock with only a few ounces of M.C.P.A. per acre, something like ½ to ¾ lb. per acre is required to do the same job when it is applied through a really efficient modern sprayer such as the 'Agro,' whilst our normal recommendation is a minimum of 1 lb. when applied through normal farm equipment. Weeds like thistles and docks need heavier applications, at least 2 lb. per acre, under most conditions, although it may be noted that better effects are often obtained on docks if a roller is run over them first to bruise them. Apparently this enables the weedkiller to penetrate and become translocated within the plant much more quickly and completely.

There seems little doubt that there is a large future for this type of product on grassland, particularly to control buttercup, but less is known about the economics of such applications so far. As a point of interest, practically the whole of the " hormone" weedkiller used in Holland is used on grassland, not on cereals.

We are frequently asked about the effect of these weedkillers on clover. The story is not so simple as we originally thought. Our first experience was that young clover was almost always entirely killed out, which suited the sports ground man but prevented the use of such products on corn crops undersown with seed mixtures containing clover. We have now found that undersown crops treated with " hormone " weedkillers in the very early stages, *i.e.*, when the crop, weeds and clover, are all small, will result in the destruction of the clover. If we wait, however, until there is a reasonable canopy of crop plants and weeds over the still small clover, then complete control of the weeds may often be obtained without appreciable deleterious effect on the clover.

The picture is not entirely clear so far as linseed and flax are concerned and we are indebted to Professor Blackman for most of the experimental work that has been done in this country. It appears that it is safe to use M.C.P.A. on linseed provided the crop is not less than 4 inches high and not greater than 12 inches ; outside these limits damage to the crop is liable to outweigh benefits in weed control. Conditions are somewhat similar on flax although here even greater care must be taken or fibre may be damaged. I believe it is possible to use D.C.P.A., *i.e.*, 2,4-D, as the sodium salt on linseed but it is too dangerous to use on flax under any conditions.

A further warning must be mentioned at this point. Whilst low-volume sprayers have been used successfully for the application of M.C.P.A. on linseed, there have also been some cases of fairly serious damage. Until we know quite a lot more about this it is perhaps a little unwise to recommend wide-scale use of low-volume sprayers on linseed, unless experience with the particular district has shown it to be safe. (By low-volume sprayer I refer to sprayers applying as little as 5 to 15 gallons of liquid per acre.)

Another crop which has increased considerably within the last year or two is peas, and particularly peas grown for canning. Here it seems that with certain varieties and under certain conditions excellent results have been obtained, particularly in the early stages of growth. On the other hand there have, again, been instances of quite severe damage. The one generalisation that seems to be sound is that the dusts are safer on peas than sprays at rates of application giving the same weedkiller effect.

HAZARDS

I cannot, of course, leave this subject without stressing one or two specific hazards. On cereal crops themselves there has seldom been any appreciable trouble except, perhaps, where applications have been made in the very early stages of growth, and particularly on oats which may be damaged to a small extent in the seedling stage. Similarly, some varieties of barley, and particularly the Scandinavian varieties such as Abed Kenia occasionally have a small percentage of malformed ears. These take the form of missing grains on one side of the head with double grains on the other. Occasionally the awns fail to emerge properly from the sheath. In general these malformations do not affect yield or the viability of the resulting grain.

Quite obviously it is necessary to take precautions to prevent these extremely active chemicals from finding their way on to susceptible crops and particularly on to such farm crops as sugarbeet, beans and any of the *Brassicas*.

I am only too well aware that this has been a very inadequate survey of a very large and important subject. I have not had time to mention potato haulm destruction, which is the subject of much experimental

work, or the special selective weedkillers which are being developed for destruction of weeds in such crops as carrots and onions. Perhaps more information will be forthcoming in the subsequent discussion.

In conclusion, however, I would like to make these particular points. No weedkiller is a panacea and none eliminates proper cultivation. Several I have mentioned have a place in modern agriculture. Their value not only to the farmer, who finds labour scarce, but also to the citizen on short rations, needs no stressing.

SUSCEPTIBILITY OF COMMON BRITISH ARABLE AND PASTURE WEEDS TO 'AGROXONE'

SUSCEPTIBLE

Two gallons or 4 cwt.—or less—per acre will kill these weeds against which consistently good results have been obtained.

WEEDS	REMARKS
BUTTERCUP, CORN A. *Ranunculus arvensis*	Treat as soon as the weed starts growing in spring with 1½—2 gallons or 3—4 cwt. per acre.
CHARLOCK A. *Brassica Sinapis* (Yellow Charlock) (Wild Mustard)	Very susceptible. One gallon or 2 cwt. per acre sufficient.
FAT HEN A. *Chenopodium album* (Goosefoot)	Use 1½—2 gallons or 3—4 cwt. per acre on seedlings. Up to 3 gallons per acre may be necessary if well grown.
Field Cabbage A. *Brassica campestris*	Locally abundant. May be confused with Charlock but flowers deeper yellow and leaves more waxy, like the cultivated cabbage. Apply 1½—2 gallons or 3 cwt. per acre to the seedling stage. Unsatisfactory results have been obtained with mature plants.
Orache A. *Atriplex patula*	As for Fat Hen.
PENNYCRESS A. *Thlaspi arvense*	One gallon or 2 cwt. per acre sufficient.
Shepherd's Purse A. *Capsella Bursa Pastoris*	1½ gallons or 3 cwt. per acre. Treat before flowering.
Treacle Mustard A. *Erysimum cheiranthoides*	1½ gallons or 3 cwt. per acre. Seedling stage.
WILD RADISH A. *Raphanus Raphanistrum* (White Charlock) (Runch)	Seedlings require 1—1½ gallons or 2½—3 cwt. per acre. If beyond this stage use 2 gallons or 3½ cwt. per acre. Best treated when with 5—6 rough leaves.

MODERATELY SUSCEPTIBLE

Use 2 gallons or 4 cwt. per acre for these weeds. Good control is usually obtained at these rates. Results not always as consistent as in column 1.

WEEDS	REMARKS
Buttercup, Creeping P. *Ranunculus repens*	Apply before flowering and again if necessary after flowering. In grassland, harrowing 10 to 15 days after treatment is very beneficial.
Cornflower A. *Centaurea Cyanus*	Seedling stage.
Dandelion P. *Taraxacum officinale*	Often killed but results variable.
Hardheads P. *Centaurea nigra* (Knapweed)	Generally killed.
Hoary Pepperwort P. *Lepidium Draba*	Best treated just before flowering.
Horsetail P. *Equisetum* spp.	Autumn applications may give best results.
Plantain P. *Plantago* spp.	Often killed at these rates.
Poppy A. *Papaver Rhoeas*	It is important to treat seedlings. Mature plants resistant.
Ragwort P. *Senecio Jacobea*	Best treated just before flowering. Spray is said to be more effective than dust.
Rushes P. *Juncus* spp.	Very promising results have been obtained, rushes often being completely killed by summer applications. It appears that cutting the rushes before applying the 'Agroxone' may greatly benefit the treatment.
Sheep's Sorrel P. *Rumex Acetosella*	Seedlings quite susceptible. Mature plants much more resistant.
Silverweed P. *Potentilla Anserina*	Variable. Killed or severely checked.
Sorrel P. *Rumex Acetosa*	Mature plants much more resistant.
Sowthistle A. *Sonchus oleraceus*	Variable. Killed or greatly checked.
Thistle, Creeping P. *Cirsium arvense*	Best treated just before flowering. When growing in a crop, treatment of young growth will kill tops and allow crop to grow away. Repeat applications necessary to kill roots of established thistles.
Tares, Vetches A or P. *Vicia* spp.	Good results have been obtained by application when weed is beginning to climb up the crop.

MODERATELY RESISTANT

Two gallons or 4 cwt. per acre generally reduces these weeds and checks their growth. Flowering may be delayed or prevented. Weeds may be killed under favourable conditions.

WEEDS	REMARKS
Bindweed, Black A. *Polygonum Convolvulus*	Young seedlings may be checked. Older plants very resistant.
Bindweed, Field P. *Convolvulus arvensis*	Apply when well grown. Tops usually killed but regrowth may take place.
Buttercup, Bulbous P. *Ranunculus bulbosus*	May be stunted and distorted. Seldom killed.
Chickweed A. *Stellaria media*	Very variable. Often considerably checked and reduced by applications to young stages.
Coltsfoot P. *Tussilago Farfara*	Checked.
Crane's Bill A or P. *Geranium* spp.	Seedlings checked.
Day-Nettle A. *Galeopsis Tetrahit*	Very variable. Sometimes killed by 2 gallons or 4 cwt. per acre.
Docks P. *Rumex* spp.	Fairly susceptible in the seedling stage. Mature plants often greatly distorted but seldom killed by one application.
Fumitory A. *Fumaria officinalis*	Seedlings reduced in number.
Groundsel A. *Senecio vulgaris* Heartsease A. *Viola tricolor*	Seedlings may be killed. Variable. Reduced in number.
Knotgrass A. *Polygonum aviculare*	May be considerably checked by application to young seedlings. Older plants resistant.
Mouse-ear Chickweed A. *Cerastium vulgatum*	Seedlings checked.
Persicary A. *Polygonum Persicaria* (Redshank) (Willow Weed)	Seedlings may be checked. Older plants resistant.
Scentless Mayweed A. *Matricaria inodora*	Seedlings checked.
Shepherd's Needle A. *Scandix-Pecten-Veneris*	Variable. Young seedlings checked and may be killed.
Sowthistle P. *Sonchus arvensis* (Perennial)	Checked.
Speedwell A or P. *Veronica* spp.	Checked.
Spurrey A. *Spergula arvensis*	Seedlings checked and reduced. Older plants little affected.
Wild Onion P. *Allium vineale*	Aerial parts have been killed by 2 gallons or 4 cwt. per acre. Inconclusive.

RESISTANT

Two gallons or 4 cwt. per acre generally has no appreciable effect on these weeds.

WEEDS	REMARKS
Bracken P. *Pteris aquilina*	
Brambles P. *Rubus* spp.	
Cleavers A. *Galium Aparine* (Herrif)	
Corncockle A. *Agrostemma Githago*	
Corn Marigold A. *Chrysanthemum segetum*	
Grasses A or P. *Gramineae*	
Mayweed—*see* Stinking Mayweed or Scentless Mayweed	
Parsley Piert A. *Alchemilla arvensis*	
Stinking Mayweed A. *Anthemis Cotula*	
Wood Sorrel P. *Oxalis* spp.	

NOTES

(1) As the susceptibility of weeds to 'Agroxone' is closely linked up with their stage and type of growth and many other factors, it is probable that the susceptibility of weeds indicated in this table will not be in complete agreement with many farmers' experience. The classification adopted above is founded upon the results of trials and observations over a number of years and in many parts of the country, and is intended to indicate the *general* reaction of common weeds to 'Agroxone.'

(2) After each English name the letter A or P denotes whether the weed is an annual or perennial, respectively.

(3) *This table should be read in conjunction with the notes on particular crops*, as rates and times of 'Agroxone' application to weeds may have to be limited by the recommendations concerning the crop.

EXTENSIVE USE OF 2,4-D

Important Canadian Agricultural Chemicals Development in 1948

By

J. W. GARVIN and A. W. HAGAR

IN 1948, just three years after the initial field experiments were started, 2-4-D was applied extensively to control many troublesome weeds. Pressed by necessity, agricultural chemical workers performed a remarkable feat in rapidly moving this chemical from the research to the commercial phase. Now its application is a vital part of the year's farming operation, particularly in the cereal and flax growing areas of Western Canada.

An estimated 3 million acres of wheat, oats, barley, rye and flax were treated on the Prairies in 1948 as compared with approximately ½ million acres in 1947. Rates of application ranged from less than one-quarter to one-half pound of 2,4-D acid equivalent per acre. As expected, the demand for suitable application equipment increased so rapidly that sprayer and duster manufacturers were unable to fill the requirements.

When selective herbicides were first introduced the Western grain growers had only a few machines suitable for an extensive weed control programme. The standard roadside and horticultural sprayers, with a tank capacity of 800 gallons and designed to apply 80 to 100 gallons per acre were not entirely suitable for Prairie conditions. In these areas water is not found in sufficient abundance to apply 2,4-D in such large dilutions. From the first, it was apparent that wide commercial use of 2,4-D would not be realised until sprayers could be designed to apply relatively low volumes of a higher concentrated water solution per acre.

In response to demand, a new type of sprayer was developed two years ago which would apply 2,4-D dilutions in water at rates of from four to eight gallons per acre. Basically these new sprayers differ from the old in that they operate at a low pressure (as low as 30 pounds per square inch) and have a new type of nozzle which is designed to eject a fine spray in the shape of a fan or a cone. Called low-volume sprayers, they are sold in two essentially different designs. One has a 20 to 30-ft. boom mounted on the front of the tractor with a tank on

the rear. The pump (usually gear pumps) is either driven from the power-take-off or pulley and under normal speeds the machine will treat 90 acres of cereal crops per day. The other is a self-contained unit with a 200 gallon tank and a 30 to 40 ft. boom mounted on a trailer. The pump is either driven from the power-take-off on the tractor or by a power unit mounted on the trailer and under normal conditions this machine will treat 150 acres per day.

Spray Formulations

To fill the requirements of all market conditions and consumer preferences, it became necessary to develop a number of 2,4-D formulations which can be divided into three distinct groups—sodium salts (dry), amine salts (liquid), and esters (liquid). The sodium salts of 2,4-D are usually formulated to contain around 70% 2,4-D acid equivalent, and are sold as a powder which is soluble in water except at high concentrations. On the basis of 2,4-D acid equivalent they are the least effective of the three groups. The most effective group, on the basis of 2,4-D acid equivalent, are the esters. Examples of the active ingredients in these are the isopropyl and butyl esters of 2,4-D and the products are formulated to contain from 30 to 40 per cent 2,4-D acid equivalent. They form white, creamy emulsions in water when mixed at the recommended rates. Intermediate in effectiveness between the sodium salts and the esters but approaching the esters, is a group called the amine salts. These are liquid concentrates formulated to contain about 40% 2,4-D acid equivalent, and having as their active ingredients such salts as the di- and tri-methanolamines and the di- and tri-ethanolamines of 2,4-D. They dissolve or disperse readily in water.

For application through the low-volume sprayers on the Prairies the ester and amine types are preferred over the sodium salt formulations. Liquid concentrates mix more readily with water and do not settle out. Factors which adversely affect the liquid formulations are the cold conditions under which the material is stored, and insoluble precipitates that form when they are mixed with water containing a relatively high percentage of alkaline salts. Solvents and adjuvants must be selected carefully to withstand temperatures of —30° F. without freezing or separating into layers, and if they do freeze it is necessary that the product should re-disperse as prepared in the original formulation. Most of the standard commercial liquid concentrates (ester and amines) are prepared to withstand extremes of these conditions.

Dust Formulations

The application of 2,4-D in the dust form was not very popular in the initial stages because of the fear that the dust would drift to valuable crops which are injured by 2,4-D, and also because of the belief that twice as much had to be applied in the form of a dust as compared to sprays for the same measure of effectiveness. Within the past two years, however, dusts have rapidly increased in popularity particularly on the open plains, where the large grain crops are grown and where there is no danger of drift to other crops. New and improved dusters have been designed and in 1948 the dust was successfully applied at rates of 5 to 8 pounds per acre with machines that would treat as much as 400 acres per day. In the dry areas of the Prairies, dusts have an advantage in that no water is required and they are quicker and easier to apply.

The 2,4-D dust formulations are prepared by spraying an oil solution of the chemical into an inert carrier such as pyrophyllite or talc. For this purpose esters are generally used because of their high degree of effectiveness and the fact that they are already prepared as an oil solution. With intimate mixing it is possible to prepare the standard 5 per cent 2,4-D acid equivalent dusts, so that they will flow readily through the dusters.

Experimental results indicate that about the same effectiveness is obtained from dusts as from sprays per unit of 2,4-D acid equivalent. In 1948 the dusts were somewhat more expensive and the average chemical costs of treating an acre were 80 cents for sprays and $1.10 for dusts. It is difficult to estimate the full cost considering labour, cost of equipment, and several other factors, but since dusters will treat more acres per day and obviate the labour of hauling water, it is possible that the per acre costs of spraying and dusting are nearly equal.

Weed Classification

To assist extension specialists and farmers, weed control authorities have classified the most important weeds according to their susceptibility to 2,4-D. Within this classification, however, there are differences because of the stage of growth of the weeds and the seasonal climatic conditions.

The Western Canada Weed Control Conference at Winnipeg in November, 1948, suggested the following recommendations for 1949.

SUGGESTED AMOUNTS OF 2,4-D ACID (AMINE AND ESTER) PER ACRE TO USE ON CEREAL OR FLAX CROPS TO CONTROL WEEDS IN WESTERN CANADA

Type of Weed and Reaction to 2,4-D	Stage of Weed Growth	
	Early 1/	Advancing
	(Ounces 2,4-D Acid per Acre)	
Annual Weeds **Highly Susceptible** ... ... Wild Mustard (*Brassica arvensis*) Stinkweed (*Thlaspi arvense*) Tumbling Mustard (*Sicymbrium altissimum*) Wild Radish (*Raphanus raphanistrum*)	3	3 to 5
Annual Weeds **Susceptible** False Ragweed (*Iva xanthifolia*) Cockel Bur (*Xanthium strumarium*) Lamb's Quarters (*Chenopodium album*) Russian Pigweed (*Axyres amarantoides*)	3 to 4	4 to 6
Annual Weeds **Partially Resistant** Russian Thistle (*Salsolakali*) Purslane (*Portulaca oleaceus*) Chickweed (*Stellaria media*) Red-root pigweed (*Aramanthus retroflexus*)	4 to 6	6 to 8
Perennial Weeds Canada Thistle (*Cnicus arvensis*) Sow Thistle (*Sonchus oleaceus*) Sweet clover Alfalfa Field Bindweed (*Convolvulus arvensis*)	Tops may be stunted or destroyed but damage to roots unlikely : 4 to 10 (*See footnote*)	
1/ Seedling and rosette stages		

FOOTNOTES

1. For the highly susceptible and susceptible weeds the sodium salt formulation may be substituted, using one and one-half (1½) times the dosages recommended in the table.

2. Cereal crops should not be treated until they have attained a height of 6 inches or until three weeks after emergence.

3. Flax should be treated as soon as weed growth warrants, providing the flax plants have already formed four or five leaves. Severe damage to flax may result if treated after the early bud stage.

4. The higher rates recommended in the table (8 ounces or more for cereals, and 5 ounces or more for flax) may at times cause some crop injury. In many cases, however, such injury will be off-set by reduction in weeds.

It is difficult to determine whether 2,4-D will give complete kill of perennial weeds because of the nature of the root stocks. Practically, this is not important because the general thinking is that 2,4-D is a control rather than an eradicant of perennial weeds. The general recommendation for eradication of perennial weeds is 1 to 2 lbs. of 2,4-D acid equivalent per acre while control is obtained with one-quarter to three-quarters of a pound and even with the high application complete kill is not usually obtained without repeated treatments.

Conclusion

The commercial use of 2,4-D has yet to approach its zenith and it is difficult to write a conclusion to its description. Experimental work is continuing, but the first phase of developing suitable formulations has passed. The scientists are now at work exploring the chemical in more detail in order to obtain a clearer understanding of its limitations in weed control, hormone effect on plants and a number of other specific properties. At the same time research is being undertaken on formulations of 2,4-D for certain limited conditions and on other chemicals to be used where 2,4-D is not entirely satisfactory. The effect of 2,4-D on the protein content of wheat and roots of corn plants, are examples of the detailed studies which are being undertaken.

Up to the end of 1948 the main educational and promotional work was directed towards the grain growers in the Prairie provinces. From here it is expected to spread to British Columbia and east to Ontario, Quebec, and the Maritimes and become an established part of farming operations in these areas. Principal interest will probably be for limited weed control on spring grains, in pastures and corn as well as for spot treatment of weed patches and along roadsides.

THE CAMPAIGN AGAINST WEEDS

Radio Talk by the Agriculturist Carl Gustaf von Hofsten of the Agricultural College

(*Translation from Swedish of an article appearing in Lantmannen* 20, 15*th May*, 1948)

Hormone Derivatives

JUST now when there is so much talk of weed campaigns, it seems timely to have a discussion on hormone derivatives which constitute the latest and most valuable contribution to this problem. However, even though hormone derivatives are superior to their rivals in weedkilling efficiency and the number of weeds controlled, the yield at harvest has been no greater by using these materials than when the older methods of weed control were used. In fact the Danes have reported better harvests after using nitrate of lime and nitrocresol, and where the latter is known to give good results it is usually the best material to use on flax.

We know that the hormones cannot be used against Couch-grass, Wild oats and other grasses. A special chlorate method has been devised for Couch-grass control, but its cost—about 150 Kroner per ha.—is out of proportion to the results usually obtained. Furthermore, experience has taught us that the risks of using chlorate are considerably greater than at first imagined. If, therefore, I advise against the chlorate method on a large scale, I do not mean in any way to dispute the favourable results obtained or to discourage further experiment. Perhaps carbamate, now under trial, may give us some useful results or alternatively we may hope for something from Virtanen's method—based on chloral and trichloracetic acid—for which a patent has just been applied. The name Virtanen certainly inspires such hopes.

The Special Case of Couch-grass (*Agropyron repens*)

Until this problem can be solved by chemical means, which is our aim, we must unfortunately make use of existing mechanical methods. I say " unfortunately " because I consider that ploughing should be only for the direct benefit of the crop. Tillage as a special measure against weeds is justified only if it is more economic or otherwise superior to other methods. An effective and harmless chemical treatment for Couch-grass might mean the disappearance of general-purpose ploughing against weeds even if the chemicals were to cost 75—100 Kroner per ha.

The difficulties of couch-grass control are apparent in all the queries we have received. I propose here to answer one of these queries. We have learnt that it is inadvisable to use a disc harrow and similar implements since by splitting the " roots " the spread of couch-grass is encouraged. This is doubly true where fields to be sown are concerned. Here raking implements only should be used and if large quantities of couch-grass " roots " come to the surface they should be collected and removed. As regards the plough many have found that it is better than other implements for splitting up the couch-grass, particularly in clay soils. This is undoubtedly right, but the green shoots should not be allowed to grow higher than 3—4 cm. before the next thorough tillage operation. The smaller and more numerous the pieces into which the " root-system " is split, the larger will be the number of shoots it develops and in consequence the sooner will it use up its reserve food supply. But the replenishment of this food supply must be prevented by timely ploughing.

Besides the grasses, coltsfoot is among those weeds with a strong resistance to hormone derivatives. Usually the cheapest and best method against coltsfoot is by treating the stubble in patches during autumn with sodium chlorate at 20 grs. per sq. m.

Hormone Preparations

We have two different types of hormone derivative : ' Methoxone ' and 2,4-D. 'Agroxone' is of the first type ; to the second belong ' Dif,' ' Philco,' Strong 2,4-D, ' Wormosan,' ' Weedone,' ' Ewoson,' ' Herbasan ' and others.

The question—" Which of these preparations is it best to use ? "—cannot be answered in general terms. We have, however, established that ' Methoxone ' preparations are somewhat more selective than 2,4-D—*i.e.*, crops are checked to a lesser degree with ' Methoxone ' whilst the effect on weeds is good for both types. This has meant that in Swedish, as in Danish and Norwegian, tests ' Methoxone ' has given a rather higher harvest yield than have 2,4-D preparations. For the same reason ' Methoxone ' should be given preference on susceptible crops such as peas, flax and perhaps also barley, which has the least resistance of all cereals.

It is, therefore, wrong to maintain that all hormone derivatives are equally good or that their efficiency is merely a question of concentrations. Equally it is wrong to say that 2,4-D is inferior.

Choice of product may be immaterial in the case of susceptible annual weeds such as charlock (*Brassica sinapis*), fat hen (*Chenopodium album*), pennycress (*Thlaspi arvense*), etc., but in advertisements prominence is often given to the cheaper price of 2,4-D, a statement which disregards the fact that ' Methoxone ' is effective against such weeds at 5—8 Kg. as opposed to the normal 10 litres of 2,4-D which to a certain extent reduces this price difference.

An important point to remember is that 2,4-D, being more potent against weeds which are difficult to eradicate, is better suited for use in *perennial grassland* where it is cheaper and more effective.

Clover and lucerne are in the class of susceptible plants so that spraying of clover or undersown cereals is not advisable. Since toxicity persists in the soil for at least a month, spraying before sowing cannot be recommended either. But autumn cereals may be undersown in spring provided spraying has been done in the autumn. Generally speaking nitrocresol and copper preparations are the only compounds which can be recommended for the protective crop.

Hormone weedkillers seem to be of great importance in *grass seed crops*. Where there is much mayweed (*Matricaria inodora*) or other resistant weeds, 2,4-D may be preferred. The poorly clovered or clover-free hay fields of Norrland can similarly be freed of such troublesome weeds as yellow rocket (*Barbarea vulgaris*), rock cress (*Arabis arenosa*) Caraway (*Carum carui*), goutweed (*Aegopodium podagraria*), parsley-piert (*Alchemilla* spp.), etc. Great hedge bedstraw (*Galium mollugo*), perhaps our worst pasture weed, is unfortunately highly resistant, at least when it is older, and cannot be eradicated once it has got a hold on the pasture.

With *peas*, 3—4 litres per ha. of 'Methoxone' preparation is advised. Although the crop is 1—2 weeks later in maturing, the yield is usually good. We know of some instances where 2,4-D in powder form gave satisfactory results. It must not be forgotten, however, that sulphuric acid at 35—40 Kg./ha. and copper preparations at 15—18 Kg./ha. are also very effective on peas.

Flax. I have already stated that nitrocresol at 10—12 Kg./ha. is to be preferred on flax in certain districts. Around Lake Vener and in East Gothland this treatment has given good results. On the other hand, the Uppland flax grower has mixed feelings regarding this treatment and in Smalanning and Hallanning they definitely do not favour it. Sulphuric acid at 35 Kg. or copper preparations at 18 Kg. are both effective, but if growers have had poor experiences with these treatments—what are the possibilities of hormone weedkillers? They certainly are harmful to the fibre, but have no deleterious effect on the seed, so they may be unreservedly recommended for linseed crops. But if annual weeds look like gaining the upper hand, something must be done even with flax and I do not hesitate to disregard the risks to a certain extent and recommend using 'Methoxone' at 4—5 Kg. per ha. If the flax remains short and looks like giving poor fibre, the crop can be taken for seed. I go so far as to believe that about 3 Kg. 'Methoxone' per ha. can usefully be employed even with moderate weed infestation.

Time of Spraying with Hormone Weedkillers

Although timing with these compounds is much the same as we have been used to with other weedkillers, it must be remembered that they are toxic also to germinating seedlings not yet above ground.

This means that spraying can begin earlier than with sulphuric acid or 4—5 days after emergence of the cereal crop, and may be continued for 2—3 weeks. The possibility of spraying at this time can be of the greatest importance both from the point of view of labour and of the effect on the weeds. Linseed can be treated partly at germination and partly when it is 8 cm. high—even up to 15 cm. high.

Reports on the susceptibility of some weeds vary considerably ; for example *Galeopsis* spp., *Polygonum tomentosum*, *Spergula* spp., *Polygonum aviculare*, *Stellaria media* and *Matricaria inodora*. This applies also to other chemical weedkillers. The reason seems to lie in the development of the weed at the time of spraying. Such weeds should be treated as early as possible.

As regards weather conditions, we know that cool weather gives the poorest results—a fact of special interest in autumn-sowing campaigns. On the other hand, it is of greater importance that they are only slightly susceptible to the effects of rain. Rain falling one hour after application has no weakening effect.

Other Crops

I have referred so far to the spraying of cereals, pasture, grass seed, peas and flax. Other crops should not be sprayed.

The hormone weedkillers should be of great importance to pastures for the control of buttercup (*Ranunculus acris*), caraway (*Carum carui*), wild carrot (*Daucus carota*), autumnal hawkbit (*Leontodon autumnalis*) and other plants which animals refuse to eat. These weeds spread rapidly if weeding is not practised or is impossible owing to the unevenness of the ground. Plantain (*Plantago* spp.), dandelion (*Taraxacum officinale*) and other undesirable plants can also be killed. Spraying should be done at the rosette stage and 2,4-D is preferred. White clover is badly damaged but is not killed.

Against corn rocket and stinging nettle (*Urtica dioica*) 2,4-D should be used in place of sodium chlorate as formerly. Corn rocket is particularly susceptible.

Spraying Fallow Land

Although nobody would fallow his land merely to give him the opportunity of spraying, the subject of spraying fallows is a very topical one just now. The Danes say it is not worth while, which I find hard to believe. For success it is essential that the weeds should have developed new shoots before spraying begins ; this is not invariably the case. Though Swedish experiments have not yet been done on this problem, 2,4-D will undoubtedly find a useful place here.

CONTROL OF WEEDS IN RICE FIELDS

PART I

Translation of an article entitled "Chemical Weed Control in Rice and Wheat" appearing in 'Risicoltura' No. 9, 1948, by R. Chiapelli.

PREFACE

THE destruction of weeds by chemicals is a method widely used in America and England with satisfactory results.

Our Institute, always awake to every agricultural advancement, has undertaken weed control experiments in rice fields which have been carried out with the greatest possible accuracy.

Tests were made in the laboratory and in the field. In the laboratory these tests were conducted in zinc tubs so as to observe and study the effect of the chemical on both weeds and rice. The results obtained have been most interesting and have given grounds for hoping that good results may also be obtained in general agricultural practice. The substance used was 'Agroxone'—from Messrs. "Solplant" of Milan—which is a product based on a plant hormone. It contains the newly found phyto-hormone 'Methoxone' discovered by Imperial Chemical Industries following many years of research concluded in 1940. This substance is a selective weed-killer inasmuch as, when used at low concentration (from 1% to 2%) it destroys some weeds, leaving the gramineae and some other plant families unharmed. The Americans have already given a detailed list of many weeds which 1% to 2% 'Agroxone' succeeds in destroying. But they do not mention weeds harmful to rice; such weeds have now been subjected by us to this treatment and we now present our observations on their behaviour.

EXPERIMENTS ON WEED SEEDS IN THE SOIL

Tests were directed to weed seeds contained in the soil as well as to growing plants. In the former various plots were laid out including treatments and controls to observe the effect of the weedkiller.

In the first series of tests rice-field soils were treated one month before sowing, on stubble. In the second series, treatment of the soil took place 15 days before sowing, on stubble and on ploughed land. The third series of tests consisted of treatment of ploughed land immediately prior to sowing.

The weedkiller was applied in both liquid and powder forms at concentrations of 1% to 3%. The results obtained from these tests were negative in that no difference could be observed between treated and untreated plots. We therefore concluded that the chemical when applied to the soil is readily changed into compounds harmless to the growth of the plants.

EXPERIMENTS ON GROWING PLANTS

Laboratory tests. On the other hand, excellent results were obtained on growing weeds and especially on the younger weed plants.

Applications at different concentrations were made on plants, sown or transplanted in tubs, after they had begun to shoot. After eight days the following results were noted :

Tub No. I. Scirpus maritimus. Concentration : 3%. Four plants dead and three plants with aerial organs still green but the base of the plant withered at the root collar. All plants died 15 days after treatment.

Tub No. II. Marsilia quadrifolia. Concentration : 2%. A few leaves faded or yellow ; the rest intact. After further treatment at 4% and higher the plants turned yellow and the leaves dried up. This species was destroyed after 20 days. *Marsilia quadrifolia* is, therefore, very resistant to treatment ; this may possibly be due to the fact that the liquid does not adhere to the leaves.

Tub No. III. Very young *Scirpus mucronatus.* Concentration : 1%. Excellent results : *Scirpus mucronatus* was wholly destroyed.

Tub No. IV. Alisma plantago and Butomus umbellatum. Concentration : 2%. Excellent results ; after a few days the leaves began to dry up until the whole plant took on the yellowish colour characteristic of dead plants. *Butomus umbellatum* showed itself more resistant and was only killed after 15 days, while on the other hand the shoots of *Alisma plantago* dried up after 8 days.

Tub No. V. Cyperus difformis and rice. Concentration : 1%. Excellent result ; *Cyperus difformis* was killed, a black circle appearing at the base due to withering of the tissues. The rice was unharmed.

Tub No. VI. Rice. Concentration : 2%. Eight days after treatment a few leaves only were yellow. Base of the plants was completely healthy. The weedkiller does not have any permanent effect on rice.

Tub No. VII. Rather old *Scirpus mucronatus,* height of shoots about 25 cm. Concentration : 2%. Most of the shoots were dry and only a few retained their green appearance. Base completely withered. After another eight days the weed was completely destroyed.

Tub No. VIII. Panicum Crus-galli (panic-grass). Concentration : 2%. In the same condition as the rice. Normal leaves, base completely healthy, free of any trace of damage. The treatment was repeated at 4% and after another eight days a slight yellowing of the leaves was noted. But it still showed a resistance to tearing which means considerable resistance to the liquid weedkiller.

Tub No. IX. *Scirpus maritimus* (young plants). Concentration: 2.5% Eight days after treatment portions of the plants had completely dried up whilst the other plants remained green. After another eight days the plants were completely desiccated.

Tub No. X. *Scirpus maritimus.* Concentration: 2%. Half the plants showed dry, yellow leaves whilst the remainder were still green. Greater resistance to treatment was due to the greater age of the plants.

Tub No. XI. *Scirpus maritimus.* Concentration: 1%. Slight effect; plants were green with yellow tops. In this case treatment was light and the plants resisted it.

Conclusion. The weedkiller gave excellent results on *Scirpus mucronatus* and on *Alisma plantago* at 2%; on *Cyperus difformis* at 1%. Good results at 3% concentration were obtained on *Scirpus maritimus*, while negative effects were obtained on *Marsilia quadrifolia*, rice and panic-grass.

CHEMICAL WEEDKILLERS IN GENERAL AGRICULTURAL PRACTICE

After completing the tub experiments, the behaviour of the rice with regard to chemical weedkillers being known, our investigations were directed to rice-fields affected by sedges and especially *Scirpus mucronatus.*

The tests were numerous and were made by various farmers using spray pumps, who applied the chemical weedkiller diluted to 2%.

A very interesting test was that carried out by Mr. Gila Giacinto of the Castellazzo farm. The area of the test was 200 sq. m. of old rice-fields planted with American 1600 rice. The land was infested with *Scirpus mucronatus*, a weed fairly prevalent in the Vercelli and Pavia districts, the common name of which is " quadritun " in the Vercelli dialect and " bech de sniepa " in the Pavian dialect.

The product used was a liquid and was applied at 2% by means of a spray pump carried on the operative's shoulder. The dosage used was 1,000 litres per hectare. A good sprayer applies on an average 500 litres per hectare. Therefore treatment was repeated twice.

Eight days after treatment the weed was completely destroyed, the rice remaining healthy.

In comparison with hand-weeding the result obtained with the chemical weedkiller was better because no plant escaped the weedkiller, whereas with hand-weeding some weeds are always left in the fields.

There remains the problem of method of application; this is a problem easily solved when it is remembered that in Monferrato there is already privately-owned spraying machinery in the form of high capacity spray pumps which can be mounted on horse-back.

The economic advantage of chemical treatment is fairly considerable —the cost of hand-weeding, when the land is heavily infested with weeds, is over 30.000 lire (£15) per day (*i.e.*, about 80.000 lire—£40— per hectare); chemical treatment costs about 12,000 lire per hectare, including cost of application (*i.e.*, 6,000 lire for the weedkiller and 6,000 lire for diluting and applying it).

With transplanted rice also there is a considerable advantage to be gained by this method; here the cost of weeding is about 26,000 lire.

The use of this weedkiller will, furthermore, confer an additional financial benefit to the farmer by making it possible for him to transplant his rice with every confidence that the weeds will be completely destroyed. Rice thus freed from weeds will be able to develop fully and without doubt give a superior yield.

CHEMICAL WEEDKILLERS IN WHEAT CULTIVATION

Vetch is unquestionably the most damaging weed to wheat crops. If it is not pulled up in time it develops in such a way as to envelop all the ears and prevent them from maturing normally, even resulting in a total loss of the crop. It is, therefore, important to act when the weed is still small in order to prevent it from attaching itself to the ears and suffocating them.

The tests with chemical weedkillers were carried out at Borgovercelli by Mr. Mattea Battista on Damiano Chiesa grain on the 22nd May, 1948. The crop was allowed to develop to about 20 cm. and was sown in rows. The vetch was still immature and measured 7—8 cm. in height. Three plots of 100 sq. m. each were laid down. In the first plot the liquid weedkiller was sprayed at 2% at the rate of 1000 litres per hectare. In the second plot the weedkiller was applied as a powder at a dosage of 3 quintals per hectare. The third plot was left as a control.

In the first and second plots, 4—5 days after application, the vetch began to show the effect of the weedkiller, the plants beginning to yellow. After 8—10 days the vetch plants were completely dried up, whilst the wheat showed no signs of damage. The control plot was overrun with vetch. We conclude that use of chemical weedkillers in the field is a practice to be strongly recommended; it was found that hand-weeding, even though done very thoroughly, does not completely destroy all the weeds.

The same results were obtained in another experiment at Crescentino, on the Monticelli farm of the Marchioness Negrotto Cambiasi Giustiniani, where growth of vetch had also assumed notable proportions.

CONTROL OF WEEDS IN RICE FIELDS

PART II

Translation of author's summary in article entitled "Application of 2,4-D for the Destruction of Weeds" in Revista de Agricultura Comercio e Industrias No. 87, Nov. 1948, by T. C. Ryker.

(*Recommendations apply to conditions in Louisiana.*)

FINAL RECOMMENDATIONS

WE feel justified in summarising what we have said in the following tentative recommendations. Their rigidity is due to the necessity of reducing as far as possible the risks of injury to rice and other crops.

1. In no case do we recommend the application of 2,4-D powder, because of the danger to neighbouring crops caused by air currents. Therefore, the following recommendations refer to the application of the acid in the form of sprays.

2. The best time to control Mexican weed (*Caperonia castacida*) and Curly indigo (*Aeschynomene virginia*) lies between the second and third week following watering. At this time, if 1 pound of 2,4-D is used per acre (on the basis of its acid equivalent) there is very little danger of the rice suffering any damage. As the purpose of the application is to kill the above-mentioned weeds the water should not be high enough to cover them.

3. If treatment is applied later, after the second or third weeks following irrigation, $1\frac{1}{4}$ to $1\frac{1}{2}$ lbs. acid equivalent per acre should be used for the control of the same weeds. If only Common indigo (*Sesbania macrocarpa*) is concerned and not Curly indigo, 1 lb. per acre will suffice.

4. If field machines are to be used, treatment should be applied before turning on the water and not more than $\frac{3}{4}$ lb. per acre should be used. The employment of a larger quantity might be injurious to the tender rice shoots. It is advisable to delay treatment as long as possible, since the more mature the plants, the less susceptible they are to the action of the acid. In order to obtain the best results the water should not be turned on before the third day after treatment nor after the sixth day.

Fig. 1. **The use of 'Agroxone' on Rice in Italy**
Left-hand plot — Rice infested with *Scirpus maritimus*
Right-hand plot — One month after treatment with 'Agroxone' showing freedom from weeds

Fig. 2.

Campaign against the Moroccan Locust in Northern Iraq
Poison bait prepared with 'Agrocide' 7 being scattered on grazing grounds amongst the foothills of Kurdistan

THE LOCUST PROBLEM

By O. B. LEAN

PART II. CONTROL TECHNIQUE

Introduction

THE locust may be attacked as egg, hopper or adult, and control may be directed against the solitary grasshopper, the swarming locust or against the intermediate *transiens* phase. The technique of killing the insect is one aspect of locust control. Equally important questions of locust control by less direct means, and the organisation of actual campaigns involving policy problems, will be dealt with in later articles.

No doubt locusts have been attacked in a primitive way since the earliest days of agriculture. In the present article we shall not attempt to trace the evolution of locust control, as any account of the innumerable methods that have been tried and subsequently abandoned and the many ingenious suggestions, from steam rollers to vacuum cleaners, are mainly past history. It will be of more value to outline locust control as it stands today and to indicate how future strategy may develop.

Destruction of Eggs

The digging up of egg fields is now generally condemned. The eggs of such species as the Moroccan locust, laid in the summer, do not hatch until the following spring, allowing ample time for ploughing. It has been found, however, that even intensive working of the soil fails to destroy all eggs, and that it is always better to wait for the hoppers to emerge and then attack them. As much effort may be involved in destroying those that escape exposure to the weather and birds as to kill the lot. The possibility of treating egg fields with such insecticides as benzene hexachloride may be worth consideration.

Hopper Control

Most present-day campaigns are directed against hoppers. This is certainly the most susceptible stage; hoppers are relatively easily found as they move about in dense bands, the compact formations permit economy of insecticides, and hoppers feed voraciously on poison bait or on poisoned vegetation.

The five hopper instars occupy four to seven weeks, according to the temperature, and throughout this period the hoppers are open to attack. For two reasons it is desirable to destroy them early. An egg field may cover hundreds of acres—even several square miles. When

the eggs hatch the hoppers of the first instar assemble in what are known as pools, each a few square yards in area and each almost solid with small, black hoppers, perhaps 5,000 to 10,000 per square yard. Within a few days the pools coalesce and all the hoppers from the egg field join up to form one large band. This is the time to launch the attack. Baiting should not begin when the first eggs hatch ; the area will only have to be re-treated as further hoppers appear. Migration then begins with the hoppers following a regular programme each day —resting, feeding or marching, according to climatic conditions— and this daily round must be appreciated if insecticides, especially poison baits, are to be used to the best advantage. As the hopper grows the size of the band extends manyfold. One worker calculated that an acre of first instar hoppers will cover 200 acres by the time they reach the fifth instar. Obviously far more insecticide is required to kill the older band, and if operations are delayed the crops suffer more and more.

Modern locust control dates from the introduction of poison bait and this technique remains the basis of most campaigns. Poison baiting succeeds because locusts, particularly in the hopper stage, are more attracted towards certain substances than to their normal food plants ; they seek out the bait and their own destruction. Bait consists of an attractive edible carrier and a stomach insecticide. Many carriers are used—bran, sawdust, horse and donkey dung, oil-seed residues, bagasse, and so on—but the choice should depend upon local availability, with waste products preferred to animal foodstuffs. Whatever the material, its effectiveness usually depends upon the amount of water it will absorb, as moisture is very attractive and few baits remain useful after they have dried out. Attention is being devoted to dry baits based on carriers which will attract the locusts over a longer period and the possibilities of dry baiting are of great importance in regions short of water and where bait is to be scattered from aircraft.

Until 1944 sodium arsenite was the normal bait poison, used at a concentration of $1\frac{1}{2}$ to 2 lbs. per 100 lbs. dry bran. When employed correctly, there was really no danger either to livestock or to the labour scattering the bait, but accidents did occur and many countries feared this effective weapon. The substitution of benzene hexachloride for arsenite overcame this difficulty and as it also kills the hopper more rapidly it soon became popular. During the recent serious plague of the desert locust in Africa and the Middle East, benzene hexachloride played an important role, particularly as it permitted the introduction of modern locust control into the most backward countries. It can be used freely on grazing land where the herdsmen soon learn that the new bait is harmless to their stock. Benzene hexachloride has proved equally successful against the Moroccan locust, the red locust, the South American locust, and in fact against all species against which it has been tested. A standard bait prepared from 'Agrocide' 7 contains 0.5% benzene hexachloride or about 0.065% of the gamma-isomer.

Locust campaigns are waged in some of the most difficult regions where it is necessary to economise in all materials in order to conserve

transport and where simplicity of equipment favours rapid work and obviates knotty maintenance troubles. Poison baiting satisfies these requirements. Bait can be applied from aircraft or with mechanical bait spreaders mounted on trucks, but it can almost equally well be distributed by hand, where labour is available, with no more equipment than a few tins or baskets in which to carry the bait.

The technique of baiting takes some time to learn if the material is to be used economically. The rate of application needed to give complete control is so absurdly low that few field men can avoid overdosing.

The daily regime of hopper behaviour is a cyclical series of responses to climate, possibly influenced by diurnal rhythmical activity. At high and low temperatures hoppers are immobile ; at intermediate temperatures only slight fluctuations determine whether hoppers feed without marching, feed whilst marching or march without feeding. The line of march is not haphazard, any more than the flight direction of a swarm, but is orientated by wind direction, light, radiation and by topographical features. The locust baiter only gradually learns to appreciate the reactions of the hoppers but ultimately he may be able to anticipate each move so that he can expend his ammunition wisely. Basically, bait is not costly but it may have to be shipped and transported many hundreds of miles before it reaches the field of operations, and transport is always a major item in locust control expenditure.

Bait must be spread when hoppers are feeding or shortly before they feed. With small bands it may be distributed amongst the hoppers at about 10 lbs. bait (dry weight) per acre, but it is usually wiser to spread rather heavier belts of bait in front of an advancing band, and where the column extends some way back, further belts across the band at right angles to the line of march. The hoppers should be left to feed and disturbed as little as possible, as one large band is easier to destroy than several smaller ones.

In spite of the ease and efficacy of baiting, some workers have continued to favour control of hoppers with contact dusts or sprays, and recently there has been a general revival of interest in such techniques. It remains to be determined whether, with the newer insecticides, they can compete with baiting. There is no doubt that the quantity of insecticide required is higher. An acre of hoppers can be killed using less than one twentieth of a pound of benzene hexachloride in bait. Applying the same chemical as a contact dust, probably five pounds would be necessary. Sprays are more reliable as their efficiency does not vary with atmospheric humidity. Dinitro-ortho-cresol (DNOC) is one of the most toxic contact poisons known but the minimum effective dosage, when applied in oil solution, is probably 1 lb. per acre. Contact dusts and sprays can only be applied by machinery, using either a few powerful blowers or many hand machines. Whatever the choice, this equipment is costly and difficult to maintain in good working order under the arduous conditions of a typical anti-locust campaign. Against these disadvantages the protagonists of dusting

and spraying claim that contact insecticides can be applied at all hours of the day and that the work is less skilled than baiting.

Anti-locust operations are planned in advance but as many last-minute adjustments have to be made the organisation needs to be flexible and the component units must be mobile. Here again baiting has its advantages as only bait need be transferred and even that should not be necessary if adequate strategic dumps have been laid down. Just as the organisation must be adaptable to meet an ever-changing situation, the methods of attack cannot be too stereotyped and no single method of control will ever meet all needs. Most locust species feed readily on bait, but other species, especially those living in rank vegetation, are less attracted, and some, like the red locust, rarely descend to the ground but remain near the tips of tall grasses and move by hopping from stem to stem. Under such conditions contact sprays or the application of a stomach poison to the natural food may be better than bait. Each set of circumstances can be weighed up by the entomologist on the spot and when a policy has been decided upon the offensive must be carried through with the utmost vigour —an anti-locust campaign can be a very strenuous affair.

One other, non-chemical, technique may be mentioned. Some countries have until recently relied upon metal barriers to trap or divert hopper bands, and in open country where infestations recur in the same locality each year the method has some advantages. At best, however, as many hundreds of miles of barrier may be required, this technique is cumbersome and lacks mobility. When I began writing this series of articles, barriers were still popular; already, like the flame-throwers, they have become obsolete.

Adult Control

When locusts breed in some quite inaccessible region or across a frontier in a state where the importance of locust control is not appreciated, the control of the adult locust becomes necessary. Only recently has serious attention been given to this problem, which is far more difficult than the attack on the more static hopper. In the fledgling stage, that is, immediately after the final moult, adults can be killed with poison bait as readily as hoppers, and this is merely an extension of the hopper campaign. Adults can also be killed with bait when they are egg-laying or when overwintering in the colder climates. The real need is to strike at active, hungry, immigrant swarms before they inflict damage and before they lay.

For some years it has been recognised that aeroplanes, and possibly helicopters, offer the best mode of attack against a swarm which migrates many miles a day. Occasionally swarms fly by night, but normally they settle at dusk and only set off again with the rise of temperature in the morning. At first it was believed that adult swarms could be tackled best when they were concentrated in their night roosts. When this was tested in the field it was found that a very extensive ground scouting organisation would be needed to track

the swarms and to relay to the air unit the settling position. The ground unit had also to demarcate the resting swarm and direct the aircraft during the spraying or dusting operations. As the swarm might fly off an hour or two after first light the ground party had little time to prepare and the aircraft only a brief period in which to operate.

Here again, one must choose between dusts and sprays. In South America dusts have been popular, beginning with DNOC applied from standard aircraft and later with BHC applied from helicopters. Believing that sprays of relatively coarse particle size can be controlled better than dusts, British entomologists have studied the problems of spraying swarms with low volumes of the newer contact insecticides, particularly when the locusts are in flight. This technique has several advantages ; operations can continue all day, the pilot can see his target, and the locusts are not shielded by vegetation. On the other hand, a swarm is far more dispersed in flight than when settled, and it will be necessary to spray very considerable areas to kill a single swarm. Recent trials with DNOC in East Africa were highly promising; excellent results with BHC are reported from South Africa and Australia, and further tests may establish air spraying and give the anti-locust organisations of the world a new weapon. The cost of aerial operations is bound to be high, but if they can prevent an invasion of a country or area, thus saving the aggregate cost of damage and of hopper campaigns, they may be worth-while. Air spraying will not supplant other methods of locust control ; it will be complementary to them, to be practised only under well defined conditions.

4th July, 1949.

COPPER SPRAYS FOR COFFEE IN EAST AFRICA

THE use of copper preparations by coffee planters in Kenya, both for leaf-rust and leaf-fall prevention, is too well-known to call for any detailed description. In this short note we confine ourselves to drawing attention to certain important details of spray timing and to the types of copper preparation best suited to this work. The results of experimental work conducted at the Scott Laboratories and at the Coffee Research Station, Ruiru, have been freely drawn upon, and in particular the conclusions published by Rayner (1), and Rayner and Jones (2).

TIMING OF COPPER SPRAYS

Broadly speaking the best times for applying copper sprays are conditioned by (*a*) the purpose for which the spray is being applied; and (*b*) the particular weather conditions prevailing at the time.

There are two perfectly distinct uses for copper as a protective spray in coffee cultivation—tonic spraying against leaf-fall and a fungicidal spray against leaf-rust (*Hemileia vastatrix*). Methods of application differ both in timing and concentration for these two purposes, and for this reason it is impossible to control both by a single combined spraying operation.

(A) Tonic Spraying

The primary object is to prevent leaf-fall occurring in the dry months following the long rains. Tonic spraying is sometimes referred to as the post-rains spray, indicating that the application is made after the long rains have set in. Insufficient data are available at present to give very precise timing instructions, but Rayner and Jones (2) suggest as a guide that operations should begin when an average of two new pairs of leaves per branch have unfolded since the beginning of the year. This will generally be in April or May, depending on the earliness or lateness of the rains.

In the majority of years this one tonic spray will be sufficient but exceptionally—as when the rains are early and persist for over ten weeks—a second application in early June will greatly repay the cost. In some high altitude districts also, a tonic spray at the end of the Short Rains has proved effective.

Tonic spraying should never be omitted whatever the weather conditions may happen to be at the time.

(B) Fungicidal Spraying

Leaf-rust activity varies from year to year and, except on estates at the lower altitudes, preventive spraying will prove economic only in years of high disease incidence. On the lower estates where the disease nearly always follows the onset of the rains, annual spraying as a routine practice may well be an economic proposition.

Unless fungicidal spraying (as distinct from the tonic spray) is carried out regularly, observations must be made in January to March each year with a view to predicting the severity of attack and thus determining if spraying is necessary. This, as Rayner (1) points out, is fortunately a comparatively simple matter. Two points must be observed : (1) Occurrence of rust spots—more than 2—3 infected leaves per bush ; (2) Alternation of showery and sunny periods at the time when the rains are breaking. Either of these two symptoms alone indicates that leaf-rust attack may be severe and preparations for spraying should be made.

The most effective time to apply the anti-Hemileia spray is during one of the fine breaks of weather as the Rains begin.

NATURE OF THE SPRAY

Experiments carried out in Kenya with a number of copper compounds both as tonic and fungicidal sprays reveal little if any difference in efficiency between the various formulations tested. Choice of material therefore rests on their relative merits as to ease of preparation and handling in addition to cost.

Preparation and handling

Preparation of such old and well established sprays as Bordeaux and Burgundy mixtures, whilst comparatively simple, involves supervision and the handling of bulky ingredients such as lime, carbide and soda crystals as well as copper sulphate. Lime, moreover, must be of the right quality and the equipment and labour used in preparation are considerable items. A further disadvantage of these older mixtures is that they must be made up in the field immediately prior to spraying. Their use on a large scale calls, therefore, for careful organisation if satisfactory results are to be obtained.

Ready-made preparations in the form of dispersible powders which only require to be added to water and stirred have obvious advantages on this score. In the Kenya experiments already referred to the cuprous oxide preparation ' Perenox ' was used. Not only is ' Perenox ' easy and pleasant in handling and mixing, but the suspension is sufficiently stable to remain fully effective even if left for several days without stirring.

The copper sulphate mixtures can easily be seen on foliage after spraying, a distinct advantage when having to rely on African labour. On the other hand a good cuprous oxide fungicide, being much more finely divided, may at low concentrations be hard to see on the leaves although giving a more even deposit of copper.

Amount and Concentration of Spray

The essential differences between the sprays required for tonic spraying and Hemileia control may be summarised as follows :—

	Tonic Spray	*Fungicidal Spray*
Concentration ...	2% Copper	¼—½% Copper
Amount	⅘ pint per tree	Up to 1 gallon per tree.

The amounts of spray applied have an important bearing on the type of equipment it is most convenient to use. For tonic spraying small quantities of a concentrated solution are applied, and although this is not easy to achieve with the type of equipment generally available, it is made simpler if it is recognised that complete coverage is unnecessary for tonic spraying.

By contrast spraying to control leaf-rust must be thorough on both upper and lower leaf surfaces. The hand or power equipment used must be capable of giving a complete, drenching spray.

Cost of Spraying

Cost of the material is by no means the sole factor to be considered here, but is unfortunately the only aspect on which we have figures for guidance. Rayner and Jones (2) have shown that at equivalent copper strengths Carbide—Bordeaux and Cuprous oxide (' Perenox ') cost exactly the same. Burgundy mixture is about 25% cheaper.

No data are available showing relative labour costs when using these materials. In this connection it is pertinent to stress the much higher quantities of solid materials which have to be handled when using Carbide—Bordeaux and Burgundy mixtures as compared with cuprous oxide. The weights of copper sulphate, calcium carbide, Magadi soda ash and ' Perenox ' dispersible powder required to make up these three compounds are, in the above order, in the proportions 11 : 13 : 2½. Taken in conjunction with the fact already mentioned that the ready-made cuprous oxide product need not be made up immediately prior to spraying, and is so easily prepared simply by adding the required amount to the water followed by stirring, its superiority as regards cost of supervision and handling will become obvious.

CONCLUSION

This brief review of salient points connected with the use of copper sprays on coffee raises a number of practical issues which can only be resolved by trial under estate conditions. The technical efficiency of copper spraying to prevent leaf-fall and as an insurance against leaf-rust is not in doubt, but for economic reasons this does not mean it is necessarily a practical proposition under all circumstances. It is hoped that the recommendations and suggestions made by Messrs. Rayner and Jones which we have outlined in this article will be given practical expression by estate managers interested in this problem.

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N.W.

THE CONTROL OF ANTS BY BENZENE HEXACHLORIDE

By D. A. TIDMAN

THE damage to agricultural crops caused by ants is a matter for the gravest concern in a number of countries in not a few of which they are reliably estimated to be economic pest No. 1. Some idea of the magnitude of this problem may be gauged from the estimate of more than 11,000 tons carbon bisulphide given by Sauer and Duval (1) as the annual requirement of the province of Sao Paulo (Brazil) to combat the leaf-cutting ant. The financial loss to the farmer is almost impossible to compute, but the fact that Governments such as that of Colombia are prepared to spend up to 50,000 U.S. dollars in a single year on control measures is a fair index of the gravity of this pest.

ANT DAMAGE

Ants take their toll of crops not only by devouring the plants, as for instance the tropical American leaf-cutting ant, but also may do untold damage indirectly by acting as foster mothers to other insect pests.

The close association between ants and scale insects or mealy bugs is well known. The coffee mealy bug—*Pseudococcus spp.* in Kenya—for example is cultivated by the ant *Pheidole punctulata Mayr.* and until cheaper biological methods came along, excellent control was achieved by grease-banding the trees. Such bands prevent the attendant ants from reaching the mealy bugs in the foliage of the coffee tree. The use of foliage insecticides is, in this case, discouraged for fear of killing the parasite *Anagyrus kivuensis Comp.*, which has been introduced for purposes of control.

Natural parasites of economic pests may also form the food of ants which thus serve to encourage the spread of the pest. Here again, ant control will lead directly to the control of the primary pest.

Two diseases of vital importance to Africa at the present time have recently been shown to owe their spread to the activity of ants. " Swollen shoot " of cacao in West Africa and possibly " sudden death " of cloves in Zanzibar are diseases caused by a virus infection. Mealy bugs (*Pseudococcus spp.*) are the vectors in the former case, a scale insect (*Coccus hesperidum L.*) in the latter. Both vector species are invariably attended by ants—a fact which has naturally fostered the hope that by controlling the ants the spread of the virus may be greatly checked or prevented.

In the case of " swollen shoot " of cacao, the most important attendant ants—*Crematogaster spp.*—are all arboreal. Control by greasebanding is therefore precluded and one approach to the solution of the problem is being sought by killing the ant by means of a foliage insecticide or an ant jelly simulating the attractive properties of the mealy bug secretion.

RECENT EXPERIMENTS ON ANT CONTROL BY BHC

The high degree of toxicity to ants shown by the gamma isomer of BHC has led in recent years to a considerable amount of experimental work directed towards finding suitable means of applying it so as to effect control at an economic cost.

Previously chemicals used to destroy ants have suffered from certain major defects. The cyanide ant poisons, though very effective, are also very poisonous to human beings. Carbon bisulphide is highly inflammable and unpleasant to handle. Benzene hexachloride is neither poisonous to humans nor inflammable. Being toxic to ants at very low concentrations it provides a cheap and safe substitute for the older remedies, provided efficient means of application can be found.

In the experiments noted here we have tried to indicate the different methods of approach that have been tried in various countries as well as the various formulations of BHC which have proved most useful.

South America

Recent trials carried out in Uruguay in order to investigate the toxicity of ' Gammexane' gamma-BHC to the common species of ant in that country, indicated that BHC products are toxic to the following species :—

Black Cutting Ant (*Atta lundi* L.)
Coloured Ant (*Atta sexdens* L.)
Little Ant (*Iridomyrmex humilis* Mayr)
Crazy Ant (*Camponotus punctulatus* L.)

It was also observed that when BHC is sprinkled as a dust at the mouth of the ant hill (as in the case of the Black Ant) and does not reach the larval chambers, its action is limited to the extermination of ants which come into contact with it. It does not exercise any action on the remainder of the colony, and for this reason it is extremely difficult to achieve total destruction of the ant hills with this method. It was also noticed that the ants are repelled by the odour of ' Gammexane " gamma-BHC, abandoning exits which have been dusted and opening others.

The effectiveness of BHC is assured in such cases as that of the Coloured Ant, whose nest is within easy reach and which can be dusted

after it has been opened up with a spade or similar tool. This is confirmed by experiments in Brazil. Using a ' Pupo ' rod* an average of seven positive perforations were made in each of three ant hills of the Leaf Eating Ant, *Atta sexdens* L. Using an oil pump a total of 500 gm. of 2 per cent gamma-BHC dust was injected into each ant hill with highly satisfactory results. Dr. Autuori, of the Biological Institute in Sao Paulo, Brazil, has shown that this species, *Atta sexdens* L., is extremely susceptible to gamma-BHC, but the difficulty, as with insects of similar habits, is to bring the material into contact with the ants and particularly the queens, so that a colony may be entirely wiped out.

Experiments in 1947 against the Black Leaf Cutting Ant, *Atta lundi* L., in Uruguay, using No. 2 Smoke Generators were disappointing. The generators were placed in hermetically sealed combustion chambers fitted with a pointed mouthpiece with a rubber tube and inserted into the inside of the ant hill. Observations made a week after the trial started, showed that life in the ant hills went on as usual. Similar experiments in 1948 confirmed the poor results obtained against *Atta lundi* L. In this case a cartridge consisting of three No. 4 generators was lighted in the entrance to an ant hill. The trial was carried out when the ants were working. The results obtained were negative as the ants continued their normal work, merely abandoning the entrance treated.

In Colombia the most important species is *Atta cephalotes* L. (Leaf-Cutting Ant). 'Agrocide' Smoke Generators have given very good results against this species, although the cost of treatment was considerably higher than the older methods of burning sulphur or pouring carbon bisulphide into the nests. Roughly 1 gm. of BHC is needed for every 15 litres volume of air space in the nest.

British West Indies

In Trinidad, considerable work has been done on the control of the Parasol Ant and it has been established that 'Agrocide' 3 dust offers a safe and reliable means of destroying nests, provided the powder is pumped into the nest itself. The amount used in these experiments was in the region of $\frac{1}{2}$ lb. of 'Agrocide' 3 per average size nest. 100 per cent control was obtained. It was also evident that 'Agrocide' 3 dust had a repellent action and this quality could be used as a temporary protection for plants just being attacked, thus providing time for tracing the nest and destroying it. During the course of these trials, 120 nests were treated by introducing a No. 2 ' Gammexane' Smoke Generator (2 oz.) into the many entrances

* **Pupo Rod.**—This is a rod about 2 metres long and $\frac{5}{8}$ inch diameter, having at the end a flat cone of slightly wider diameter than the rod. This instrument can be forced into the soil, and if it passes into an ant excavation chamber, this can be felt by the lack of resistance on the rod. When the chamber is located the rod is withdrawn. If the chamber is active, ants will immediately issue from the hole, thus live chambers can be marked for subsequent treatment. This system is very practical and outlines the areas of the nests to be treated very rapidly.

and tamping off other vents and holes from which the gas might escape. Out of the 120 nests so treated only one was not a complete success, and this single failure occurred with a very large nest (2,000 square feet superficial area) of the *Atta octospinosa* Reich. species. The results of these trials made it appear that the first members of the colonies to be directly affected are the " fungus garden " attendants. The effect of this is that the mycelium grows unattended and commences to spore generously, under which conditions it is apparently unsuitable as a diet. Whether the ultimate destruction of the nests is due to this phenomenon or solely to the insecticidal action of the ' Gammexane,' or both, has not been fully determined.

Preliminary experiments in British Guiana against the " Coushi " or Parasol Ant *Atta cephalotes* L. indicate that 'Agrocide' Smoke Generators, which proved so efficient against *Atta octospinosa* Reich. in Trinidad, will control the former species providing the smoke can be introduced into the chambers, a far from easy task.

Field results from more recent experiments in British Guiana (2) show that No. 4 'Agrocide' Smoke Generators give a very much higher mortality than any of the other chemicals employed in the experiment. In this instance, the size of the nest was 75-ft. by 18-ft., and 20 pellets were introduced into the nest. 50 per cent of the nest was destroyed and rehabitation commenced two months later.

Similar experiments carried out in British Guiana, in which three nests of " Coushi " Ants were dealt with, showed that 'Agrocide' Smoke Generators were very successful. Inspection of the nests six weeks after treatment revealed no sign of life at all and it must be assumed that the queen was destroyed and the fungus beds poisoned to a sufficient degree to preclude the return of the ants.

Asia

In India *Oecophylla smaragdina* Fab. attacking fruit trees was repelled for 14 days by dusting the trees with a 5 per cent BHC dust. A 2 per cent BHC dust, blown into broken leaf nests of this species, was very effective.

Experiments in United Provinces, India, have shown a 5 per cent crude BHC dust at full strength to be very effective for keeping ants out of beehives. This dust is now placed in cups in which stand the legs of the stools on which the beehives are placed. Since using the ' Gammexane' gamma-BHC no ants have been observed crawling up and down the legs of the stools.

In experiments against ants (species unnamed) attacking tobacco seed beds in Java, 'Agrocide' 3 at 44 lb. per acre (0.28 lb. gamma-BHC per acre) gave an excellent kill and did not appear to affect seed germination. At 88 lb. per acre, 'Agrocide' 3 inhibited germination of the tobacco seeds. Against *Formica sanguinea* Latr. on potato tubers, trials showed that a 5% BHC dust at 50 lb. per acre applied to the base of young plants gave very good control.

South Africa

In South Africa a preliminary experiment with ' Gammexane' gamma-BHC, as an ant banding material, has proved very promising. In this test bands or strips of sacking dipped in various 'Gammexane' gamma-BHC formulations were applied to trees severely infested with ants. Bands painted with a paste containing corrosive sublimate were used for comparison with the ' Gammexane' treated trees.

After three days a small percentage of ants were crossing the sublimate bands. There were practically no ants in the trees of which the trunks had been painted with ' Gammexane' dip paste or dust. After a week, there was quite a general crossing of the corrosive sublimate, but in all the ' Gammexane' treatments the ants had disappeared entirely from the immediate vicinity of the trees. After two weeks considerable crossing of the corrosive sublimate bands was taking place. In the ' Gammexane' treatments no ants were to be found on trunks, even below the bands.

Australia

Information from New South Wales (3) indicates good control of *Iridomyrmex rufoniger* Lowne by dusting. In this experiment, a 10 per cent BHC dust sprinkled on a large mound and placed in the tunnel entrance, followed by disturbing the ants by scraping the surface of the nest, caused the inhabitants to pour out in vast numbers, climb grass and weak stems in an endeavour to escape the fumes, and literally die in cascades. Similar treatment also gave high kills of *Iridomyrmex detectus* Smith.

U.S.A.

It was found in Rhode Island in 1948 (4) that ant hill construction by the Corn Field Ant, *Lasius americanus* Emery, a serious pest of fine turf, was reduced by 46.5 per cent using a 50 per cent wettable BHC preparation (6% gamma-BHC) at the rate of 1 lb. 50 per cent. wettable powder in 20 gallons water per 100 square feet, well watered in.

CONCLUSIONS

It would appear that BHC in dust, liquid and smoke preparations is toxic to most ant species and control with this material should be obtained, providing contact between the insecticide and the ant is made. It is evident that further work needs to be done on methods of application in order to devise ways and means of placing the chemical in the chambers of deep nests.

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